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1 ***Version Abrégée***

Aujourd'hui les études archéobotaniques et isotopiques s'accordent sur un foyer de domestication du millet en Chine au cours du VIII[e] millénaire avant notre ère et sa diffusion à travers l'Eurasie jusqu'à la côte Atlantique au cours de l'âge du Bronze. Pourtant, depuis plusieurs décennies, la littérature archéobotanique mentionne la présence de grains de millet dans des niveaux néolithiques au carrefour de l'Asie et de l'Europe (Ukraine, Géorgie et Azerbaïdjan). Le projet ANR ORIMIL, dont le présent article en retrace les origines, la mise en place jusqu'à l'acquisition des données et la restitution des résultats, avait ainsi pour ambition de vérifier, pour la première fois, à partir d'une approche intégrée multi-paramètres, si cette région du Sud Caucase avait également été un foyer de domestication et d'expansion du millet. Si oui, à partir de quand et comment ?

2 **Les origines du projet : un programme pluridisciplinaire de recherche, à l'initiative du Musée des Confluences de Lyon**

3 Lors de la préparation de l'exposition permanente du nouveau Musée des Confluences à Lyon, le sujet de la tombe 9 de la nécropole de Koban a été réexaminé dans une perspective palethnologique (fig. 1). Découverte au XIX[e] siècle en Ossétie du Nord dans le Caucase par Ernest Chantre, et confiée au Musée, cette tombe avait été attribuée

chronologiquement au début de l'âge du Fer. Outre des études des paramètres biologiques, des pratiques funéraires et des objets en bronze accompagnant le défunt, ainsi qu'une nouvelle datation radiocarbone, une analyse paléo-alimentaire a été réalisée sur plusieurs squelettes de Koban et sur d'autres venant de nécropoles voisines et contemporaines (un sujet du site de Kislovodsk-Nord Caucase en Kabardie ; trois sujets de la nécropole de Samtavro-vallée de la Kura, près de Tbilissi) (fig. 2). Trois ossements animaux, déposés en offrande dans la tombe 9, ont également été analysés. Les rapports isotopiques du carbone et de l'azote ont été dosés sur la fraction organique des squelettes (collagène) dans le but de restituer la nature des protéines consommées. Les rapports isotopiques du carbone ($\delta^{13}C$) permettent de distinguer les consommateurs de céréales, comme le blé, l'orge, l'avoine (C3, valeurs basses), de ceux consommant du millet (C4, valeurs hautes) et de ceux s'alimentant des ressources d'origine marine (valeurs hautes). Tandis que les rapports isotopiques de l'azote ($\delta^{15}N$) permettent, en raison du fractionnement isotopique entre l'alimentation et le consommateur, de distinguer les consommateurs occasionnels de protéines animales (valeurs basses), de ceux qui s'en nourrissent plus régulièrement tout comme ceux consommant des ressources marines (valeurs hautes).

4 Les collagènes humains caucasiens tous bien préservés, à l'exception d'un sujet de Samtavro, montrent des valeurs de $\delta^{13}C$ hautes comprises entre -18,7 et -10,0 ‰ (-15,5 ± 2,7 ‰, n = 9) et de $\delta^{15}N$ entre 7,0 et 10,4 ‰ (9,2 ± 1,1 ‰, n = 9) suggérant la consommation de ressources enrichies en ^{13}C (fig. 3). Les sujets de Koban, avec des valeurs hautes de $\delta^{13}C$ et des valeurs plutôt basses de $\delta^{15}N$ relativement à leur faune, indiqueraient une faible contribution des protéines animales et donc une consommation directe d'une plante alimentaire en C4. Compte tenu de la localisation géographique des sites loin de la mer, une alimentation dominée par des ressources marines, même de faible niveau trophique, paraît très peu probable. En revanche, compte tenu de leur datation, la consommation de millet (*Panicum miliaceum* et *Setaria italica*), deux céréales en C4, apparait la plus envisageable (fig. 3). Les valeurs des sujets caucasiens sont tout à fait comparables à celles identifiées pour des consommateurs de millet en Europe et en Chine (fig. 2). Cette étude a également permis de montrer que si cette céréale était consommée, les quantités absorbées ne sont pas similaires entre tous les sujets (pourrait-il s'agir d'un facteur social et familial ?). Elle a également permis de réfléchir au statut du millet par rapport à d'autres espèces très courantes (blé, orge) et de poser la question de la culture de cette céréale en milieu montagnard.

5 Malgré les nombreuses incertitudes inhérentes à cette étude préliminaire, ces résultats ont apporté pour la première fois la preuve isotopique de la consommation de millet dans cette région du monde au début de l'âge du Fer. Toutefois, comme aucune donnée ne documentait de façon précise les origines de la culture de cette céréale dans le Sud Caucase, en dépit de sa place privilégiée au carrefour de l'Asie et de l'Europe, nous avons élaboré et proposé le projet ORIMIL.

6 **Le projet ORIMIL : approches méthodologiques**

7 Afin de cerner au mieux la présence et la consommation du millet, les développements les plus récents de l'archéologie, l'anthropologie, l'archéozoologie, l'archéobotanique, la géomorphologie et la biogéochimie isotopique ont été considérés. Nous avons ainsi mis en place un projet de recherche reposant sur une approche pluridisciplinaire, jusque-là inédite par son ampleur géographique et politico-scientifique sur plus d'une trentaine de

sites –en cours de fouilles ou anciennement fouillés– sur les territoires actuels de l'Arménie, de l'Azerbaïdjan et de la Géorgie (fig. 4).

8 D'un point de vue méthodologique, une première partie du projet a été consacrée à l'étude du contexte environnemental et économique en rapport avec la culture du millet. Le cadre environnemental de cette région, dont la diversité écologique est très importante, a été décrit pour les périodes pré- et protohistoriques, grâce à différentes approches : les marqueurs géoarchéologiques et géomorphologiques afin de restituer les paléo-paysages et les surfaces cultivables, et plusieurs études palynologiques sur des séquences naturelles pour définir l'évolution du paysage et l'impact anthropique sur ce dernier. Les restes végétaux, témoins directs de la culture du millet, retrouvés en contexte archéologique, sous forme de graines, mais aussi sous forme de phytolithes ont été analysés. Ces études ont été complétées par l'analyse chimique des composés libérés par le millet dans les sédiments (miliacine). Les marqueurs correspondant aux traces laissées par les végétaux sur les outils utilisés pour la préparation alimentaire (mouture/décorticage), et mis en évidence par l'analyse de tracéologie optique, ont également été étudiés. Une deuxième partie du projet a été consacrée à la caractérisation et la quantification de la consommation du millet chez les hommes et les animaux, à partir d'analyses isotopiques (carbone, azote) réalisées sur les fractions organique et minérale des tissus osseux des consommateurs (animaux et humains).

9 **Le projet ORIMIL : premiers résultats**

10 L'analyse archéobotanique n'a pas identifié de grains de millet dans les niveaux néolithiques. En revanche, des datations radiocarbone réalisées directement sur des grains de millet provenant de 16 sites, du Nord-Est de la Turquie au Nord du Caucase (Russie) ont permis de mettre en évidence un début de culture, en particulier de celle du millet des oiseaux (*Setaria italica*) au Bronze moyen, vers 2000-1700 avant n.è. L'interprétation de ce corpus de dates est en cours et permettra très prochainement de reconsidérer les modalités d'apparition de cette céréale dans la région, en corrélation avec l'ensemble des résultats des études archéobiologiques.

11 En Géorgie, sur les plateaux du Petit Caucase et dans la Plaine de la Kura, les analyses paléoécologiques et géochimiques de séquences naturelles et archéologiques ont révélé un climat plutôt favorable entre le Néolithique et les âges des métaux (fig. 5). Ce contexte climatique favorable serait à l'origine d'un important développement forestier sur les montagnes et dans le secteur de Tbilissi, tandis que la vallée de la Kura et celle de la Iori auraient conservé leur caractère steppique au cours du temps. D'ailleurs, l'analyse géochimique des sédiments de plusieurs sites localisés dans ces deux plaines alluviales n'a révélé aucune trace de miliacine.

12 Les données géoarchéologiques ont permis de mettre en évidence une relation entre les modifications paysagères à proximité de la vallée de la Kura et les variations du niveau relatif de la mer Caspienne affectant la disponibilité en terres cultivables et les modes d'occupations des sociétés au cours du Néolithique et jusqu'à l'âge des métaux.

13 L'analyse du macro-outillage (meules et mortiers) a montré une place variable de la transformation des céréales au Néolithique et au Chalcolithique ainsi qu'un réel changement des techniques à partir de la culture Kuro-Araxe (Bronze ancien, 3300-3000 avant n.è.), avec l'apparition d'un type de meule spécifique, considéré comme un marqueur culturel, permettant de broyer des quantités plus importantes de céréales (fig. 6). Des prélèvements en surface des meules et mortiers de plusieurs sites (Mentesh

Tepe, Gadachrili Gora) n'ont toutefois pas permis de vérifier si ces outils avaient été impliqués dans la transformation du millet.

14 Les analyses isotopiques ont montré, que les sujets néolithiques et chalcolithiques, n'ont pas mangé de millet, corroborant les résultats des études archéobotaniques. Que ce soit dans la vallée de la Kura ou de l'Araxe, les pratiques alimentaires des sujets découverts sur les sites d'Aknashen et de Mentesh Tepe apparaissent hétérogènes, témoignant soit de choix alimentaires distincts selon les individus, soit d'une mobilité récente des hommes. Au début du Bronze ancien (culture Kuro-Araxe), l'étude du site de Chobareti, à 1800 m d'altitude (sud Géorgie), révèle que seules des céréales C3, comme le froment et le blé amidonnier (graines et restes de battage), sont cultivées ; quant à l'alimentation, elle est centrée sur une économie mixte incluant les céréales et une part significative de viande de bœuf et de chèvre ou mouton. L'alimentation paraît similaire entre tous les sites Kuro-Araxe d'altitude ainsi qu'entre les individus d'un même site, suggérant soit une diminution de l'éventail des ressources alimentaires disponibles soit une mobilité de groupes humains partageant de profondes affinités culturelles (fig. 7a et b). Finalement, pour le Sud Caucase, la preuve isotopique la plus ancienne d'une consommation significative de millet, par les animaux et les hommes, est datée de la première moitié du II^e^ millénaire avant n.è., à proximité de Tbilissi (fig. 7c). La consommation de millet s'intensifierait à la transition entre l'âge du Bronze récent et l'âge du Fer, sans toutefois devenir uniforme (fig. 7d).

15 Pour conclure, les résultats montrent que le Caucase n'a été ni un foyer très ancien de domestication, ni de consommation du millet, contrairement à la Chine, puisque sa culture est attestée dans la région dans la première moitié du II^e^ millénaire avant n.è., soit à la fin du Bronze moyen. La culture du millet se serait donc développée ici à des dates comparables à celles mentionnées en Europe occidentale. La qualité et la quantité des données obtenues, notamment isotopiques, permettront prochainement de préciser le facteur à l'origine de la diffusion de cette céréale d'est ou ouest (facteur climatique ou socio-culturel). Afin de compléter cette histoire des plantes alimentaires, une des perspectives serait d'étudier la route empruntée par le millet et les hommes pour atteindre la vallée de la Kura (steppes eurasiennes/plaines de l'Iran).

Introduction

16 At the core of part of the new permanent exhibition of the Musée des Confluences[1] in Lyon, a burial discovered in North Caucasus and housed at this institution, was re-examined in a "palaeo-ethnological" perspective. The Caucasus is a region of Eurasia, located between the Black Sea to the west and the Caspian Sea to the east. It connects Europe to Asia by the Great Caucasus mountain range. To the north of the Great Caucasus extends the Ciscaucasia with several republics from Russian Federation, as for instance the North Ossetia and Kabardino-Balkaria. While to the south of the Great Caucasus, the Transcaucasia corresponds to the three present-day countries of Georgia, Azerbaijan and Armenia. This region, characterized by a mosaic of environments due to a strong climatic gradient between the west (wet subtropical) and the east (semi-arid continental), combined with the effect of the altitudinal gradient, is of great interest for study the modifications of the past lifestyles and the know-how transmissions across the Caucasian isthmus. In such a context, the new investigation of the Tomb 9 (artefacts and human skeleton, fig. 1), discovered by Ernest Chantre in the 19th century in the necropolis of

Koban in North Ossetia (Chantre 1886), was carried out using the latest techniques for the study of archaeological and biological materials. The radiocarbon analysis revealed that this individual lived between the 10th and the 9th centuries BC at the beginning of the Iron Age (Lyon-4369 Oxa: Age ^{14}C BP: 2735±30, 967–813 cal. BC, C. Oberlin, UMR 5138, Lyon). In addition to analyses of morphological features and funerary practices[2], one of the objectives was to reconstruct the nature of the consumed protein resources using the analysis of stable isotope ratios (δ^{13}C and δ^{15}N) (Herrscher & Goude 2015). In order to place this individual within a wider environmental context and population-based approach, stable isotope analyses[3] focused not only on the individual in Tomb 9 but also on other skeletons excavated by Ernest Chantre in this region: six from the Koban necropolis, one from the site of Kislovodsk (North Caucasus in Kabardino-Balkaria) and three from the necropolis of Samtavro (South Caucasus in the Kura valley, near Tbilisi ; fig. 4). Three animal bones (*Ovis* sp. and *Sus* sp.) deposited in Tomb 9 of the Koban burial were also analyzed to provide information on the isotopic characteristics of the domestic resources in the environment near the Koban site.

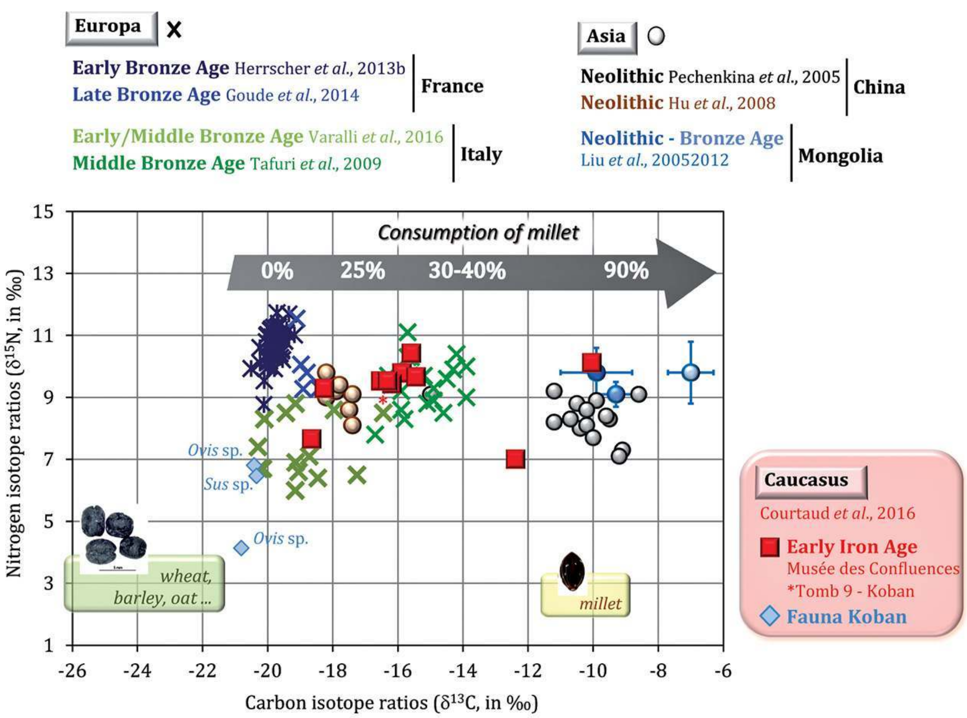
1. Reconstitution of Tomb 9 from the Koban necropolis, part of the permanent exhibition "Éternités, visions de l'au-delà" at the Musée des Confluences

© photo Olivier Garcin

17 Apart from one individual from Samtavro, the nine other human samples and the three animals present the guarantees of good collagen preservation (DeNiro 1985, Ambrose 1990). The δ^{13}C values of the animals (between -20.8 and -20.3‰) are characteristic of a C3 environment (Bocherens 1999 ; fig. 2). Humans have high δ^{13}C values between -18.7 and -10.0‰ (mean±1 SD=-15.5±2.7‰, n=9) and δ^{15}N values between 7.0 and 10.4‰ (9.2±1.1‰, n=9) (fig. 2). Such values, above -17‰, point to the consumption of food resources enriched in ^{13}C. Given the distance from the archaeological sites to the sea and the lack of

correlation between δ15N and δ13C values, the most evident hypothesis is the consumption of a C4 staple plant. Considering the chronological period and the local environmental context where C4 plants are poorly represented, and available data on the history of millet cultivation, the hypothesis of millet consumption would be the most plausible. The high δ13C values of these individuals match perfectly with the typical values of millet consumers in Europe and China (fig. 2). With regard to the Koban individuals and the associated fauna, the high human δ13C values and low δ15N values would indicate a direct consumption of millet, in the form of porridge or pancakes, for example, and a low contribution of animal proteins.

2. Comparison of carbon and nitrogen isotopic ratios for wheat and millet consumers in Eastern Asia (China, Mongolia), in Europe (France, Italy) and in Caucasus (Russian Federation, Georgia)

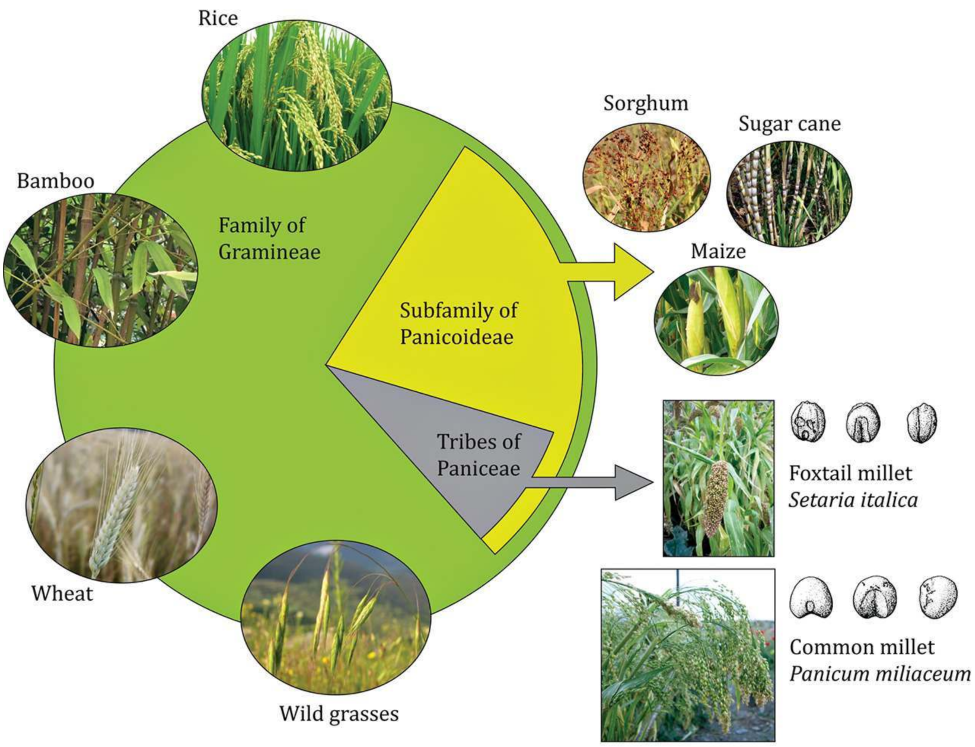


18 Despite the many uncertainties inherent to this preliminary study, these results have for the first time provided irrefutable isotopic evidence of millet consumption -actually two: common millet (*Panicum miliaceum)* and Italian millet (*Setaria italica*)- in this region of the world at the beginning of the Iron Age (Herrscher *et al.* 2009, 2010), Beyond the feeding behaviour of these Kobanian populations, this raises the question of millet cultivation history in the Caucasus region. More generally, while the expansion of millet is attested at least 8 000 years before our era from the most eastern confines of China during the Neolithic to the Atlantic frontier of Europe during the Iron Age (Lu *et al.* 2009, Barton *et al.* 2009, Lightfoot *et al.* 2013), no data accurately record the cultivation of this cereal in the Caucasus, in spite of its privileged position at the crossroads of Mesopotamia and Asia/ Europe. How did millet come about in the South Caucasus? Could this area constitute another center of domestication? This broad debate on the history of plants and food practices contributed to the ORIMIL research project and the objectives, means and initial results of this project are presented in this article.

Domestication of millet: Current state of the art

19 The domestication of plants precedes that of animals and constitutes a major stage in the evolution of human societies. The question of domestication is an old issue, directly related to the neolithisation process. First cereals (wheat, barley) were domesticated around 9,000 BC in the Middle East's Fertile Crescent, while millet appears to have been domesticated in eastern Asia, and possibly in the Caucasus, where a wild form also exists. Millets in the broad sense belong to the large *Gramineae* family (bamboo, rice, wheat, maize, etc.) and to the *Panicoideae* subfamily, which includes common millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) (fig. 3). In Eurasia, the vernacular term "millet" thus covers these two distinct species. They grow in temperate climates, appreciate heat and are tolerant to drought and poor soils. Millets do not require irrigation, and are among the cereals which have the shortest vegetative cycle, from 60 to 90 days (Cappers & Neef 2012, Zohary *et al*. 2012). For these reasons, and for their nutritional value (high protein, vitamin and mineral content), the cultivation of these two cereal species may have been another food source for pre- and protohistoric societies. Although it is not the most commonly cultivated cereal, sporadically, common and foxtail millets are widely distributed from Asia to Europe. This cereal has been and is still destined for food for humans but also for animals (Moreno-Larrazabal *et al*. 2015).

3. Millet: morphology, position within the *Gramineae* group (*Poaceae*)



photos: © L. Martin, E. Messager, H. Evin; drawings: © D. Baudais in Curdy *et al*. 1993

Archaeobotanical and biomolecular remains of millet

20 Botanical macro-remains, such as seeds, or specific molecules, such as miliacin[4], identified in archaeological sediments, seem to show that the domestication of millet commonly dates back more than 8,500 years before our era in China (Lu *et al.* 2009, Barton *et al.* 2009, Heron *et al.* 2016). Foxtail millet appeared to have been cultivated later, around 3,800 BC (Nasu *et al.* 2007). Common millet then expanded eastwards through Eurasia, reaching Central Asia and Northern India, during the third millennium, the steppes of Kazakhstan at the end of the second millennium, and Central and Western Europe and the Near East during the first millennium BC (Frachetti *et al.* 2010, Miller *et al.* 2016, Motuzaite-Matuzeviciute *et al.* 2013, 2015, Zohary *et al.* 2012). For the Southern Caucasus, data do not appear to be consensual. Previous publications reported the presence of millet grains in Georgia and Azerbaijan since the Neolithic era (Lisitsyna 1984, Lisitsyna & Prischchepenko 1977, Wasylikowa *et al.* 1991), whereas recent archaeobotanical studies of Neolithic archaeological layers, in the Araxes valley in Armenia, have not been able to identify their presence (Hovsepyan & Willcox, 2008).

21 Recently, the direct radiocarbon dating of charred millet seeds attributed to archaeological levels dating from the Neolithic period, between the 6th and 5th millennia, in Eastern and Central Europe, demonstrated that they were much younger than expected, and finally dated to the Bronze Age and the Medieval period for some of them (Motuzaite-Matuzeviciute *et al.* 2013). Indeed, millet grains are so small that unlike other archaeological objects, such as ceramics and bones, they can migrate downwards through archaeological layers, from more recent to older layers, without it being possible to detect their displacement during excavation. Thus, in addition to the morphological identification of millet grains at the scale of the archaeological sites, it was therefore essential to directly date the grains themselves, which is currently the only way to prove their age. Our research project focused on the research, identification and dating of archaeological millet grains from Caucasian sites.

Millet consumption revealed by isotopic markers

22 The identification of millet grains is a direct marker and provides indisputable evidence of its use, but it nonetheless remains difficult to prove its consumption from a quantitative point of view, and to determine whether it was intended for animals or humans. For these reasons, the chemical content of human and animal skeletons has been analyzed. Among the chemical markers used to reconstruct past food intakes (Herrscher & Goude 2015), stable isotopes of carbon are of particular interest for the identification of millet consumption. Indeed, like maize and sorghum, millet is isotopically distinguishable from all the other consumed cereals (wheat, oats, barley, rye, rice) and plants (vegetables, fruits) in more temperate regions. Millet has very high carbon isotopic values -typical of C4 plants, around -12‰ -, whereas all the other edible cereals and plants have significantly lower values -typical of C3 plants, around -27‰- (Smith & Epstein 1971). On account of the considerable difference between both types of plant, it is possible *a posteriori* to identify and quantify their respective consumption.

23 The identification of carbon isotope values of millet, in different parts of Western China, demonstrated its culture and consumption, by cattle and humans, since the Early

Neolithic, some 6,900 BC (Barton *et al*., 2009, Liu *et al.* 2012). Millet consumption appears to be very variable, ranging between 25 and 90%, from one site to another, and its geographical and chronological origin has still not been fully elucidated (Hu *et al.* 2006, 2008, Pechenkina *et al.* 2005, Atahan *et al.* 2011; fig. 2). In Central Asia, millet was consumed during the Bronze Age by humans from the Siberian steppes (Svyatko *et al.* 2013) and from Kazakhstan (Motuzaite-Matuzeviciute *et al.* 2015). In the meantime, interestingly, some authors have demonstrated the presence of other C4 plants, such as some wild grasses, that mimic the isotopic values of millet consumption (Iacumin *et al.* 2004, Shishlina *et al.* 2012, Hollund *et al.* 2010). In Western Europe, isotopic evidence confirms the absence of millet during the Early Bronze Age (Herrscher *et al.* 2013b), while others confirm millet cultivation and consumption during the Middle Bronze Age in Italy (Tafuri *et al.* 2009, Varalli *et al.* 2016) and during the Late Bronze Age in France (Goude *et al* . 2017; fig. 2). In contrast, during the Iron Age, results appear to be more homogeneous with constant typical values of millet consumers from the Eurasian steppes to the borders of Western Europe (Murphy *et al.* 2013, Svyatko *et al.* 2013). However, unlike China, where all the individuals within a group seem to consume similar quantities, in Europe the millet contribution to the diet appears very variable from one individual to another, raising the question of different dietary practices related to social, cultural and geographical factors (Murray & Schoeninger 1988, Le Huray & Schutkowski 2005, Murphy *et al.* 2013, Goude *et al.* 2015). For instance, during the earliest periods in China, millet consumption might be linked to high social status (Lightfoot *et al.* 2013), whereas the Iron Age series from Croatia reveal that it might be related to a lower social status (Lightfoot *et al.* 2015).

The ORIMIL project

Context and objectives

24 The Caucasus is a natural crossroad between Mesopotamia at the south and Europe and Asia at the North and also cultural and economic crossroad especially during the Neolithic and Protohistory. The complex neolithisation process of these regions, during the 7th millennium BC, is still not fully understood. In the Kura basin, the earthen architecture and material culture of the Neolithic culture, called Shulaveri-Shomu and dated to 6,000 years BC, show a strong connection with contemporaneous North-Mesopotamian and Anatolian cultures (Badalyan *et al.* 2007, Lyonnet *et al.* 2012, Nishyaki *et al.* 2015, Hamon *et al.* 2016). The question of the mobility of these people, for the acquisition and exchange of mineral resources, or pastoralism, has also influenced our perception of the economic changes in these populations living in contrasted environments, between plains and mountains.

25 The ORIMIL project aimed at the issue of the millet crop origins in the South Caucasus on a period of four millenniums between the Neolithic and the Iron Age involving both the study of the palaeoenvironmental contexts and the economic, social and cultural organization of societies. Although the preliminary analyses of several Caucasian individuals (see section above) were consistent with the consumption of more than 50% millet at the beginning of the Iron Age, the limited number of analyzed (animal and human) samples, as well as the small number of archaeological sites considered, did not provide a clear picture of millet expansion and consumption in the Caucasus. Therefore,

the search for pertinent isotopic proxies of millet consumption by humans and animals, coupled with direct dating, was also a cornerstone of our project, which aimed to enhance our understanding of food production economies among the environmental diversity of this region.

26 In such a context, the questions raised here are the following: can this region of the Caucasus be considered as a hotbed of domestication of this cereal? If so, from where and when? To this end, the objectives were to identify the first traces of millet in the different localities and to define how they demonstrate the cultivation of this cereal. Based on a precise chronology of this culture at a regional level, the ultimate goal was to discern whether millet history corresponded to isolated events or to a step-by-step dissemination from a centre of domestication.

Approaches and indicators implemented in the project

27 The domestication and cultivation of plant species leave traces that can be identified in archaeological sites. Plant domestication results in changes in their morphology and their presence in the form of charred remains attests to their use for domestic purposes. Vegetable residues (starch, phytoliths, etc.) can be found in stone, e.g. food preparation tools (hulling/milling). Evidence of cultivation and consumption of cereal can also be recorded in the biological tissues of human or animal consumers. In order to better identify the presence and consumption of millet, an integrative multi-proxies study was proposed. A first indicator concerns plant remains that are grains/phytoliths, as well as the chemical study of the compounds released by millet in the sediments (grains/ phytoliths).

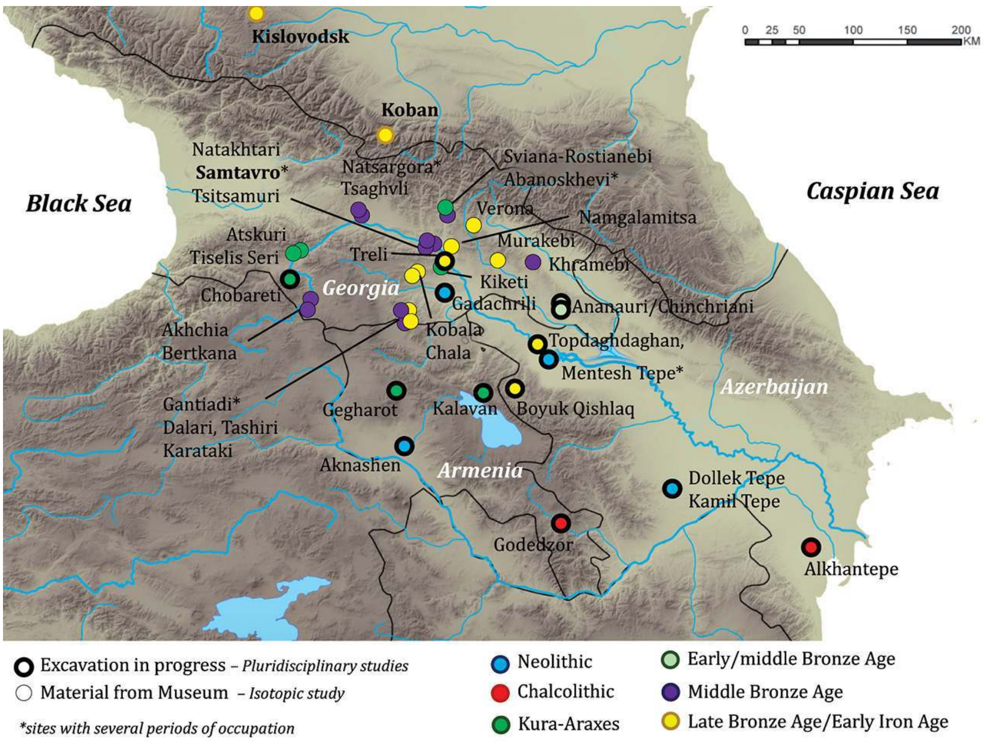
28 The second corresponds to stable isotope ratios (carbon, nitrogen) measured in the organic and mineral fractions of bone/dental tissues of consumers (animals or humans). Stable carbon isotope ratios can be used to distinguish the consumers of cereals, such as wheat, barley, oats (C3, low values), from those consuming millet (C4, high values) (O'Leary 1988) and marine resources (high values) (Schoeninger & DeNiro 1984), depending on their environment and the type of photosynthesis. While stable nitrogen isotope ratios can discriminate between occasional consumers of animal proteins have lower $\delta^{15}N$ values than those consuming animal proteins more regularly (O'Connell *et al.* 1999), and lower values than those consuming marine resources (Schoeninger & DeNiro 1984). The mechanisms involved in recording isotope ratios in tissues are complex and relate to both physiological processes and the quality of the food itself (Katzenberg *et al.* 1999, Robbins *et al.* 2005, Herrscher *et al.* 2013a). Similarly, environmental factors (aridity, vegetation cover, acidity) and anthropogenic factors (natural fertilizers) can alter the isotope values of plants at the base of trophic chains and consequently those of consumers (Schwarcz *et al.* 1999, Rodière *et al.* 1996, Bogaard *et al.* 2007). From a th eoretical point of view, isotope transfers between two consecutive trophic levels are globally considered to be predictable, with low isotopic fractionation for carbon (between 0-2 ‰) and higher fractionation for nitrogen (3-6‰) (Bocherens & Drucker 2003, O'Connell *et al.* 2012). Thus, by comparing the isotope values of the identified palaeo-dietary resources (plant remains/animal bones) in the "archaeological" environment and human isotope values, it is possible to estimate the relative contribution of the different food resources (Herrscher & Goude 2015).

29 Finally, this multidisciplinary project also included: geo-archaeological and geomorphological markers, to understand the palaeo-landscapes and the cultivable areas and lastly, markers corresponding to the traces left by plants on the tools used to prepare food (grinding/hulling), as demonstrated by use-wear analysis. Finally, in order to chronologically calibrate our results, numerous radiocarbon dates were measured on organic sediment, archaeobotanical and (animal and human) bone materials.

The selected archaeological sites

30 In order to obtain the most reliable data and to combine as many indicators as possible at archaeological site level, sites were selected because they had been recently excavated, or because the excavation was still in progress during the course of the project (fig. 4). Thirteen archaeological sites were selected: Aknashen (Badalyan *et al.* 2007) in Armenia, Mentesh Tepe[5] and Kamil Tepe[6] in Azerbaijan (Lyonnet *et al.* 2012, 2016) and Gadachrili Gora[7] in Georgia (Hamon *et al.* 2016) for the Neolithic period and Godedzor[8] in Armenia (Chataigner *et al.* 2010), Mentesh Tepe and Alkhantepe[9] in Azerbaijan for the Chalcolithic. The Early Bronze Age (Kura-Araxes period) consist Chobareti[10] in Georgia and Kalavan 1[11] (Poulmarc'h *et al.* 2016) and Gegharot[12] in Armenia. The end of the Early Bronze Age is documented by the recent discoveries of kurgans at Ananauri[13] in Georgia and Mentesh Tepe in Azerbaijan. Finally, the Late Bronze Age and Early Iron Age are represented by Treligorebi settlement and the funerary site of Treli[14] in Georgia, as well as two graves in Azerbaijan, Boyuk Qishlaq[15] and Topdaghdaghan[16].

4. Location of the archaeological sites in the South Caucasus selected for the ORIMIL project



in bold: sites involved in the preliminary study

31 In addition, to carry out the most exhaustive spatial and temporal study, the skeletons discovered during earlier excavations and housed at National and Regional Museums were integrated into the project. They correspond to 19 Georgian sites dated between the Kura-Araxes and the Iron Age (fig. 4). The selection criteria of the collections were the presence of archaeological documentation and the optimal preservation of bone remains. The majority of human material comes from the Anthropological Center[17] and the National Museum of Georgia in Tbilisi. The animal bones were also sampled in several archaeological deposits in Dusheti, Mtskheta, Dmanisi, as well as at the Municipal Archaeological Museum of Kashuri.

32 The status and function of the archaeological sites, in particular seasonality and functional specialization (hunting camps, sites related to mining activity, pastoral activities, funerary sites, etc.), were also be taken into account in order to understand dietary differences and the economic groups in the Caucasus during these periods.

First results of the project

Reconstruction of landscapes and cultivable areas

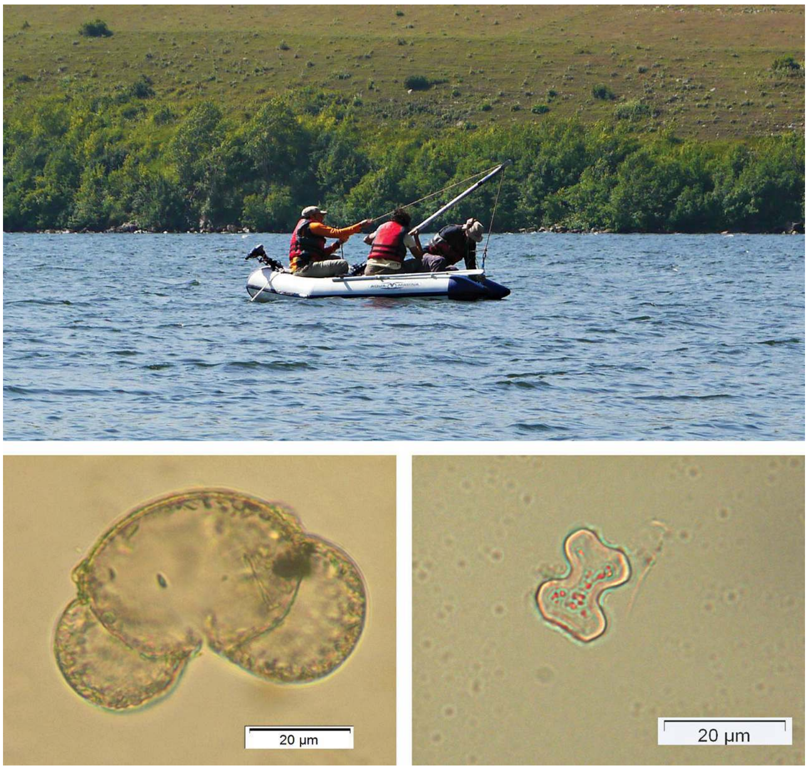
33 By cross-checking the geomorphological data with Holocene vegetation dynamics, the objective was to identify the most suitable (or unsuitable) arable lands and the best chronological periods for natural or anthropogenic development of millet. The determination of the available spaces conducive to millet cultivation, as well as the climatic contexts and the necessary soil qualities for its development, is based on a thorough analysis of the landscape and morpho-sedimentary changes. Our results proposed a first framework of the regional sedimentation rates and a partial identification of the origin, drivers and possible impacts of Holocene landscape changes on the societies living near the Caspian Sea. In addition to the impact of climatic variations, our results indicate that river sedimentation rates respond well to changes in the relative Caspian Sea level over the last few millennia (Ollivier *et al.* 2015, 2016). Upstream hydrosystems react to marine regressions by powerful regressive incisions and to transgressions by imposing phases of backfilling. Feedback is expressed in intramountain areas located at considerable distances from the shoreline (several hundred kilometers). These different sedimentary balances and the changes induced in the river morphology affect the availability of arable land, especially in areas with rivers. The modes of occupancy of the societies occupying the valleys and terracing systems of the Kura hydrosystem (river and tributaries) were affected by these landscape changes during the Neolithic and up to the Metal ages (Ollivier *et al.* 2016). This is also spatially and diachronically reflected in site location (depending on the sedimentary, soil and water accessibility facilities), as well as by their abandonment modalities and their disappearance as a result of erosion or landfill. Climate changes and baseline variations (correlated to the different sea levels) are currently being modelled and integrated into geoarchaeological analyses of land use in the Caspian hydrographic basin.

Detecting the millet signature in natural and archaeological context

34 The aim was to describe the palaeoecological and landscape context in order to detect the presence of millet and, more generally, of C4 plants in the vegetation cover in the pre-

and protohistoric deposits. Different types of analyses (pollen, phytolith, miliacin) were undertaken on natural cores and archaeological sites. The identification of grains is sufficient to confirm the presence of common and foxtail millet, whereas the analysis of phytoliths and pollen grains can only help to pinpoint the Panicoideae subfamily to which these two species belong. Several coring surveys were carried out in Georgia on the plateaus of the Lesser Caucasus but also in the Plain of the Kura. The palaeoecological and geochemical analyses of these new sequences allow us to reconstitute the history of the vegetation in different sectors (fig. 5). The results reveal a clear climatic improvement from the Neolithic period to the Bronze and Iron Age, with different types of environment in the diverse sectors. The climate favoured significant forest development on the mountains and in the Tbilisi area, but the plain between the Kura and the Iori valleys seems to have maintained its steppe vegetation over time. Our analyses did not detect the presence of millet because no miliacin was recorded (Audiard 2015), but they showed that the abundance of plants of the Chenopodiaceae family (several species of which are C4 plants, Pyankov *et al.* 2010) in the eastern plains may have had an impact on herd feeding, thus leaving a C4 footprint not necessarily due to the consumption of millet.

5. Tabatskuri lake coring in Georgia (top), pine pollen grain (bottom, left), *Panicoïdeae* phytolith, millet subfamily (bottom, right)



35 Although the literature mentions the presence of millet at several Caucasian sites since the Neolithic (Hunt *et al.* 2008), we did not find them. Nevertheless, thanks to the cooperation of Georgian, Armenian, Russian, Australian and German archaeobotanists, we were able to sample millet grains from 16 sites, from north-eastern Turkey to the northern Caucasus in Russia, in order to date them directly by radiocarbon dating. Depending on the sites, the dating of millet grains does not always correspond to the chronocultural assignment of the levels from which they originate. We were unable to obtain millet grains from the Neolithic site, and the grains from the Early Bronze Age all

yielded more recent radiocarbon ages, either from the Late Bronze Age or the Early Iron Age. Up until now, the earliest seed we have dated is a foxtail millet sample dating from the Middle Bronze Age, around 2000-1700 BC. The interpretation of this corpus of dates is in progress and will very soon allow us to reconsider the modalities of the appearance of this cereal in the region, in correlation with the results of the archaeobiological studies described below.

36 The markers observed in the material culture correspond to the traces left by food preparation on tools such as grinding stone revealed by optical use-wear and phytolith residue analyses. In order to determine the place of millet in the diet of Neolithic and Protohistoric populations, we carried out a functional analysis of macro-tools and a direct study of the plant remains (carbonized remains and phytoliths) found on archaeological sites. Characterizing changes in farming and diet practices can help to identify subsistence patterns (farming and pastoral practices), lifestyles (physical inactivity, mobility), and more generally socio-economic conditions that may have favoured the cultivation and consumption of millet.

37 Concerning archaeological data, functional study of macrolithic implements (grinding, pounding, crushing and polishing tools) is based on a use-wear analysis of several Neolithic and Protohistoric archaeological contexts of the Caucasus (Hamon 2007, 2008, Hamon *in* Lyonnet *et al.* 2012). The analysis of this material shows that the role of cereal processing in food practices varies greatly according to the lifestyle and the economy of each group (fig. 6). The first results indicate a tangible change in cereal processing techniques since the Kura-Araxes period. A much more technologically advanced type of grinders and querns, used to grind larger quantities of cereals, may have spread during this period, going as far as becoming a true cultural marker. It corresponds to a rupture in the methods of cereal treatments, as well as in the economic status of cereals in these populations at the onset of the Early Bronze Age. Tests conducted on the surface of grindstones and mortars from several sites (Mentesh Tepe, Gadachrili Gora) did not identify the presence of or millet phytolith or starch, suggesting that these tools were not involved in the modification of this cereal from the Neolithic to the Early Bronze Age.

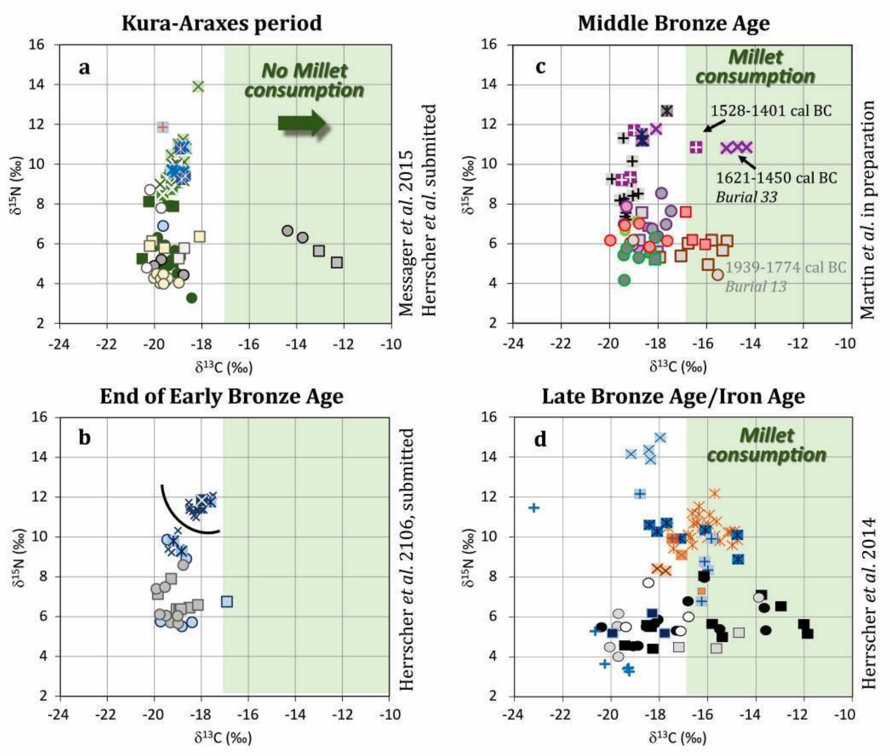
6. Kura-Araxes basalt quern and grinder (Mentesh Tepe, Azerbaïjan, Lyonnet *et al.* 2012)

Human and animal consumption of millet

38 Carbon isotope ratios ($\delta^{13}C$) measured on more than 600 human, animal and botanical samples showed that the earliest Neolithic and Chalcolithic individuals did not cultivate or eat millet, corroborating previous studies (Hovsepyan & Wilcox 2008, Decaix *et al.* 2016). In the Kura or Araxes valleys, dietary practices of the populations of Aknashen and Mentesh Tepe appear to be heterogeneous, reflecting either different individual food choices, or recent human mobility (Herrscher *et al.* 2015, 2016a). During the Early Bronze Age (Kura-Araxes period), the study of humans buried at the Chobareti site at an altitude of 1,800 m a.s.l. in Southern Georgia revealed that only C3 plants were consumed (probably cereals present in the form of seeds and threshing remains of wheat and barley), and that the diet was focused on a mixed economy, including cereals and a significant proportion of beef and goat or sheep meat with freshwater fish (fig. 7a, Messager *et al.* 2015). Regardless of the altitude of the Kura-Araxes sites, the diet appears to be similar at all sites and for all individuals at the same site, suggesting either a decrease in the range of available food resources at that time, or the mobility of human groups with deep cultural affinities (fig. 7a, Herrscher *et al.* submitted). The end of the Late Bronze Age is marked by the appearance of monumental burials containing several deceased, the kurgans. Like for the Neolithic period, the analysis of skeletons from the Ananauri and Mentesh Tepe kurgans showed no consumption of millet and inter-individual dietary variability, raising the question of a social and cultural factor (fig. 7b, Herrscher *et al.* 2016b). Finally, for the Southern Caucasus, the earliest isotope evidence of significant millet consumption by animals and humans is dated to the first half of the second millennium, near Tbilisi (fig. 7c). The multi-proxy study (grains, phytoliths,

miliacin and isotopes) carried out on the Treli-Treligorebi site, during the transition from the Late Bronze Age to the Early Iron Age, demonstrated the presence of millet cultivation and consumption by domestic animals and humans, of up to 40% (Herrscher *et al.* 2014). However, this pattern does not appear uniform among all individuals, during the Late Bronze Age or the Early Iron Age. Indeed, several individuals discovered to the east of Tbilisi, in Georgia and in Azerbaijan, showed no evidence of consuming this cereal (fig. 7d). Could this be a form of regional particularism? Environmental and climatic data do not support a regional hypothesis. Could the invasions mentioned for the most recent periods explain the mosaic of food behaviour? Is it due to the presence of migrants whose isotope data would reflect their recently abandoned habits or customs or the adoption of new cultural practices? An analysis of the mobility of human groups would be of great interest in order to advance this issue.

7. Stable carbon and nitrogen isotopic ratios of Caucasian humans and domestic animals, dated from the Bronze Age



crosses: humans, *round*: caprid, *square*: bovid

Conclusion

39 After the initial analysis of the archaeological evidence (botanical, isotopic, geomorphological, archaeological), it is now possible to begin to partially restore the history of millet cultivation and consumption in the Southern Caucasus. Our results show that the Caucasus was not an early hub of millet consumption, unlike China, since millet cultivation and consumption is only attested in the region in the first half of the 2nd millennium BC, during the Middle Bronze Age. Millet cultivation would have developed there at comparable dates to those mentioned for Western Europe (Tafuri *et al.* 2009,

Cabanis *et al.* 2010, Bouby 2011, Ferrage-Toulemonde 2013, Varalli *et al.* 2016). Some authors have hypothesized that a climatic factor is responsible for the eastward spread of this cereal (Miller *et al.* 2016), while others have more recently shown that it might be a gradual diffusion in relation to the circulation of objects and sources of raw materials (Lightfoot *et al.* 2013). Without today's tangible evidence for this second hypothesis, the millet occurrences recorded in the Caucasus, mainly in Georgia, do not appear to be related to more arid climatic conditions.

40 The ORIMIL project results from the close collaboration between the Musée des Confluences and the CNRS and is presented in detail (origin, objectives) on digital media in the "Éternités, visions de l'au-delà" part of the permanent exhibition. The results of each discipline; botany, geomorphology, macro-tool technology, food anthropology, were presented at a symposium held in November 2015 at the Musée des Confluences in the presence of many Caucasian colleagues and specialists of the history of millet. This project has opened numerous research prospects. In order to complete this history of food plants, at least one important aspect requires further attention. This concerns the route taken by millet and people to reach the Kura valley from the steppes of Central Asia, involving either crossing the Great Caucasus in the north, or taking a more southern route by Turkmenistan and Iran. This is another research program that needs to be developed.

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NOTES

1. The permanent exhibition is “Eternités, visions de l’au-delà” directed by C. Bodet, in charge of scientific programming and C. Sermet, director of exhibitions at the Musée des Confluences in Lyon.

2. The anthropological study was conducted by P. Courtaud (PACEA, Bordeaux), F. Le Mort (Archéorien, Lyon) (Courtaud *et al.* 2016).

3. For collagen preparation, see Herrscher 2003. The isotopic ratios were measured with a Europa Scientific 20-20 isotope mass spectrometer coupled to an elemental Europa Scientific 20-20 analyzer (CF-IRMS) at the Iso-Analytical Limited (Cheshire, UK). International standards used in the analysis include beef liver (IA-R042), ammonium sulfate (IA-R045), beet (IA-R005) and sugar cane (IA-R006). The reproducibility of the measurements is ± 0.1 ‰ for $\delta^{13}C$ and $\delta^{15}N$.

4. Miliacin is an aromatic compound released by millet in archaeological sediments. Its presence is detectable by chemical analyses, see Jacob *et al.* 2008.

5. Excavations directed by F. Guliyev and B. Lyonnet. The archaeological levels at Mentesh Tepe range from the Neolithic to the Early Bronze Age.

6. Excavation directed by T. Aliyev and B. Helwing.

7. Excavation directed by M. Jabaladze and C. Hamon.

8. Excavation directed by P. Avetisyan and G. Palumbi,

9. Excavation directed by T. Akhundov. The unpublished study of the burials was carried out by M. Poulmarc'h.

10. Excavation directed by K. Kakhiani and A. Sagona.

11. Excavation directed by C. Chataigner and B. Gasparyan
12. Excavation directed by R. Badalyan and A. Smith.
13. Excavation directed by Z. Makharadze
14. Excavation of the settlement were conducted by G. Bedianashivili, excavation of the funeral site by Mr. Abramishvili
15. Excavation directed by F. Guliyev and B. Lyonnet
16. Excavation directed by P. Pasha oglu, F. Guliyev and B. Lyonnet
17. Directed by Liana Bitadze

ABSTRACTS

This paper aims to present the context, the methodological approaches and the results of a research project, called ORIMIL and funded by the French National Research Agency (ANR). An integrative multi-proxy analysis, in collaboration with the Musée des Confluences in Lyon, has been designed to identify whether the region of the South Caucasus was also a hotbed of millet domestication and expansion, like China. The results from the fields of anthropology, archaeozoology, archaeobotany, geomorphology and isotopic biogeochemistry for the territories of Armenia, Azerbaijan and Georgia did not reveal the presence of an early Neolithic or Early Bronze Age hub of millet domestication. Isotopic data associated with direct radiocarbon dating on bones showed that millet was consumed by animals and humans at the earliest towards the end of the Middle Bronze Age (1621-1450 cal BC) in Georgia. These results are in keeping with (1) the numerous direct radiocarbon dates on charred millet seeds and (2) the geomorphological studies showing an increase of better soil quality and cultivable areas during the Neolithic and Bronze Age periods in the Kura valley.

Cet article vise à présenter le contexte, les approches méthodologiques et les résultats d’un projet de recherche, nommé ORIMIL et financé par l’Agence Nationale pour la Recherche (ANR). Une approche intégrée multi-paramètres, en collaboration avec le Musée des Confluences de Lyon, a été élaborée pour déterminer si la région du Caucase (Arménie, Azerbaïdjan, Géorgie et sud de la Russie) a été, à l’instar de la Chine au Néolithique, un foyer de domestication et d'expansion du millet. Les résultats des études anthropologique, archéozoologique, archéobotanique, géomorphologique et de la biogéochimie isotopique réfutent la présence d'un ancien foyer de domestication du millet au Néolithique tout comme au début de l’âge du Bronze. Les données isotopiques, associées aux datations radiocarbone des humains, montrent que le millet était consommé par les animaux et les humains au plus tôt vers la fin de l'âge du Bronze moyen (1621-1450 cal BC) en Géorgie. Ces résultats s’accordent (1) avec les nombreuses datations radiocarbone réalisées directement sur les graines de millet carbonisées et (2) les études géomorphologiques montrant une meilleure qualité du sol et une augmentation des superficies cultivables dans la vallée du Kura du Néolithique à l’âge du Bronze.

INDEX

Keywords: Southern Caucasus, Prehistory, Bronze Age, Panicum miliaceum, Setaria italica, archaeobotany, geoarchaeology, stable isotopes
Mots-clés: Caucase, Préhistoire, âge du Bronze, Panicum miliaceum, Setaria italica, archéobotanique, géoarchéologie, isotopes stables

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